legislate land use controls, and sponsor emergency preparedness planning and training. Local (i.e., city, county, town, and village) governments may impose land use controls, contribute to damage prevention through construction permits, and develop emergency preparedness plans (TRB 1988).

Office of Pipeline Safety

The distribution of pipeline regulatory responsibility has evolved since the enactment of the Natural Gas Pipeline Safety Act of 1968, which was the first legislation to require OPS to establish minimum federal safety standards for interstate natural gas transmission and distribution pipelines. The interstate commerce clause was broadly interpreted in this act so that federal regulations extended to intrastate as well as interstate natural gas pipelines. Section 5(a) of the Natural Gas Pipeline Safety Act provides for a state agency to assume all aspects of the safety program for intrastate facilities by adopting and enforcing the federal standards, while Section 5(b) permits a state agency that does not qualify under Section 5(a) to perform certain inspection and monitoring functions. The majority of the states have either 5(a) certifications or 5(b) agreements, while nine states act as interstate agents (FERC 2003c).

A cost-reimbursement formula is used that enables states to recover up to 50 percent of their costs from the federal government. As of 1999, 49 states were certified to implement the intrastate natural gas program, 9 states served as agents to administer the interstate natural gas program, 4 states were permitted to inspect intrastate natural gas or liquids facilities but had no enforcement authority, 12 states were certified to implement the intrastate liquids program, and 4 states served as agents to administer the interstate liquids program (Pates 2000). However, OPS is now in the process of phasing out the interstate agent program because it believes that additional congressional appropriations for OPS preclude the need for interstate agents.

Although federal safety regulations for liquids pipelines were promulgated in 1967, many of the regulations were general in nature and limited to interstate pipelines (TRB 1988). The Federal Railroad Administration of USDOT had regulatory authority for liquids pipeline safety until this authority was transferred to OPS of USDOT in 1972 (Congressional Research Service 1986, 118).

The Hazardous Liquid Pipeline Safety Act of 1979 allows for shared governmental responsibility for pipeline safety. Although regulation of the design, construction, maintenance, and operation of natural gas and hazardous liquids pipelines is primarily a federal responsibility, a federal–state partnership is encouraged in which the federal government sets and enforces national safety standards for interstate pipelines but states may perform day-to-day inspection and administrative duties. A state can be certified by OPS to assume jurisdiction over interstate liquids pipelines if it has adopted federal standards and does not impose more stringent standards (except for siting new pipelines) that are incompatible with federal standards (Pates 2000).

OPS is currently mandated to develop safety regulations and other approaches to ensure the safe transportation of natural gas and other hazardous materials by pipeline. OPS carries out this directive by regulating the design, construction, testing, operations, maintenance, and emergency response of pipeline facilities. Many of the regulations are written as performance standards, which set the minimum level of safety and allow the pipeline operator to use various technologies to achieve it.

In addition to regulating pipeline safety, OPS is tasked to ensure that people and the environment are protected from the risk of pipeline incidents. Thus, OPS's responsibilities include improving and expanding regulations, assessing risks, mandating the repair of defects in a timely manner, communicating information, developing performance measures, providing assistance to local communities, supporting state partners, and promoting damage prevention and the advancement of technology.

Traditionally, OPS has carried out its oversight responsibility by requiring all pipeline operators to comply with uniform minimum standards. Because pipeline operators face different risks depending on such factors as location and product being transported in the pipeline, OPS began exploring the concept of a risk-based approach to pipeline safety in the mid-1990s. The Accountable Pipeline Safety and Partnership Act of 1996 directed OPS to establish a demonstration program to test a risk management approach to pipeline safety, which involved identifying and addressing specific risks faced by individual pipeline operators rather than applying uniform standards regardless of the risks. This "act, together with a presidential memorandum to the Secretary of Transportation, requires OPS to evaluate . . . whether a risk management approach to pipeline safety can achieve a level of safety and environmental protection that is greater than the level achievable through compliance with the current pipeline safety regulations" (GAO 2000, 17). The Risk Management Demonstration Program allowed individual companies to identify and focus on risks unique to their pipelines. Since the program's initiation in 1997, OPS has approved six demonstration programs.

OPS has moved forward with the Integrity Management Program. The program for hazardous liquids pipelines allows pipeline operators flexibility to design and implement the program on the basis of pipeline-specific conditions and risks. By December 31, 2001, operators of long-distance hazardous liquids pipelines (i.e., pipeline systems of at least 500 miles) were required to have identified pipeline segments that can affect high-consequence areas. By March 31, 2002, they were required to have developed a framework for their company's integrity management program and a plan for conducting baseline assessments. Similar rules were issued for operators of small hazardous liquids pipelines (i.e., those less than 500 miles long) with later deadlines. For hazardous liquids pipelines, a high-consequence area is defined as a populated area, an area unusually sensitive to environmental damage, or a commercially navigable waterway.

The final rule for integrity management of natural gas transmission pipelines in high-consequence areas [published on December 15, 2003 (68 *Federal Register* 69778)] went into effect in February 2004. This rule requires operators of natural gas transmission pipelines to develop integrity management programs for pipelines located where a leak or rupture could do the most harm (i.e., could affect high-consequence areas). The rule requires gas transmission pipeline operators to perform ongoing assessments of pipeline integrity; to improve data collection, integration, and analysis; to repair and remediate the pipeline as necessary; and to implement preventive and mitigative actions. For natural gas transmission pipelines, OPS is developing a definition that focuses on populated areas (GAO 2002; Cycla Corporation 2004). The definition of a high-consequence area may require additional protection for people with limited mobility such as inhabitants of day care centers, old age homes, and prisons (C-FER Technologies 2000).

Federal Energy Regulatory Commission

Although federal regulations promulgated by OPS deal with pipeline safety issues, they do not address such issues as pipeline siting and financing. These issues are often a matter of negotiation between pipeline companies, landowners, and local government zoning boards. FERC is responsible for authorizing the construction and operation of interstate natural gas pipelines and issues certificates of public convenience and necessity for such pipelines. It is also responsible for addressing issues concerning environmental impacts of interstate natural gas pipelines, which often affect siting and routing, financing, and tariffs.

For natural gas transmission lines, FERC's Office of Energy Projects addresses landowner and environmental concerns by encouraging collaboration among parties, addressing stakeholder concerns before the certification process, incorporating environmental conditions into certificates, and ensuring compliance with conditions. However, USDOT and FERC signed a Memorandum of Understanding on Natural Gas Transportation Facilities, dated January 15, 1993, giving USDOT exclusive authority to promulgate federal safety standards used in the transportation of natural gas. An applicant must certify that it will design, install, inspect, test, construct, operate, replace, maintain, and inspect the facility for which a certificate is requested in accordance with federal safety standards [Section 157.14(a)(9)(vi) of FERC's regulations] unless it has been granted a waiver of the USDOT requirements in accordance with Section 3(e) of the Natural Gas Pipeline Safety Act. FERC accepts this certification and does not impose additional safety standards (FERC 2003c, 3.12-2).

When a natural gas pipeline company is planning to build an interstate pipeline, a notice of intent to prepare an environmental assessment or an environmental impact statement (EIS) is prepared and sent to federal, state, and local agencies; environmental groups; and landowners of the properties that might be affected. The notice requests comments from interested parties, after which FERC prepares an environmental assessment or an EIS outlining its findings and recommendations. An EIS describes the positive and negative effects of the proposed undertaking and cites possible alternative actions. This is followed by another comment period. Comments received are addressed in the final EIS or the final order granting or denying the pipeline a certificate. In the case of liquids pipelines, if there is a need for any major federal permits, the issuing agency would serve a role similar to that of FERC for natural gas projects.

Other Federal Agencies

U.S. Environmental Protection Agency

EPA, whose mission is to protect human health and to safeguard the natural environment (air, water, and land), develops and enforces regulations (i.e., sets national standards and issues sanctions and takes other actions when the standards are not met). When FERC is required to prepare an EIS for a proposed pipeline, EPA reviews and responds to the filed impact statement.

EPA is a regulatory agency. As such, it enforces many regulations that affect the transport of natural gas and liquids via pipelines. For example, under the Clean Water Act (33 U.S.C. § 1251) as amended by the Oil Pollution Act of 1990 (33 U.S.C. § 2701), EPA can seek injunctions and civil penalties against oil pipeline companies for discharge of oil into navigable waters of the United States and adjoining shorelines.

Bureau of Land Management

The Bureau of Land Management within the Department of the Interior is responsible for the management of public lands and is principally responsible for issuing right-of-way permits authorizing pipelines to cross federal lands (FERC 2002).

Bureau of Reclamation

The Bureau of Reclamation within the Department of the Interior is responsible for managing, developing, and protecting water and related resources in an environmentally and economically sound manner. It may grant rights-of-way for pipelines (FERC 2002).

Bureau of Indian Affairs

The Bureau of Indian Affairs within the Department of the Interior is responsible for approving rights-of-way for pipelines across lands held in trust for an Indian or an Indian tribe (FERC 2002).

Fish and Wildlife Service

The Fish and Wildlife Service within the Department of the Interior is responsible for the conservation, protection, and enhancement of fish, wildlife, plants, and their habitats. Applicants for pipeline construction projects are required to consult with the Fish and Wildlife Service on projects that could affect any of these resources. The Fish and Wildlife Service may also authorize use by permit for areas within the National Wildlife Refuge System (FERC 2002).

National Transportation Safety Board

The National Transportation Safety Board (NTSB) investigates significant accidents in all transportation modes, including pipelines, and issues safety recommendations aimed at preventing future accidents. NTSB attempts to determine the probable cause of pipeline accidents involving a fatality or substantial property damage or releases of hazardous materials, as well as selected transportation accidents that involve recurring problems. NTSB identifies major safety issues that are provided to the Research and Special Programs Administration's OPS as action items, but NTSB does not regulate equipment, personnel, or operations, and it does not initiate enforcement action.

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EIA	Energy Information Administration
FERC	Federal Energy Regulatory Commission
GAO	General Accounting Office
TRB	Transportation Research Board

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APPENDIX D

Risk Assessment Techniques in the Pipeline Industry

During the past two decades, emphasis on pipeline safety has shifted from response to prevention of accidents. Preventive actions have included greater levels of inspection, involvement of the public through communications, and prospective analysis of the dangers presented by pipelines. Pipeline companies also began to use various risk assessment techniques, including hazard and operability (HAZOP) analysis, fault tree analysis, scenario-based analysis, and indexing methods. Most analyses focus on specific factors affecting the probability of pipeline failure (e.g., internal corrosion, external corrosion, pipeline loading) or on the consequences of rupture (such as heat intensity, thermal impact radius, depth of cover). Some of these analyses focus on specific pipeline system components, while a few attempt to take component interdependencies into account. Some of the more commonly used techniques are described below.

The pipeline risk assessment and management approaches that have been published to date, regardless of the methodology used to obtain the probabilities and consequences of processes and events leading to risk, emphasize the calculation of a risk number (i.e., a mathematical product of probability and consequence). Although this calculation allows a quantitative comparison of the effect of different factors on pipeline safety, it is not adequate to define risk to the public. As outlined in Chapter 3, such a risk is better characterized in terms of the three questions posed (known in risk assessment as the risk triplet).

Recently, the U.S. Department of Transportation's Office of Pipeline Safety (OPS) implemented a new regulatory approach—the Integrity Management Program—that establishes new testing, repair, and mitigation requirements for transmission pipelines and requires pipeline companies to use a risk-based approach for pipeline safety. Under the program, liquid and natural gas pipeline operators, as a first step, will be required to perform risk assessments on each of their pipeline segments in high-consequence areas. Inspections will be performed by the use of in-line inspection tools, analysis of operating and maintenance records, and direct examination of pipe in selected areas. Risk criteria have been considered in other countries, including societal risk due to land use near pipelines (IGE 2001; Committee for the Prevention of Disasters 1999).

CURRENT APPROACH TO RISK ASSESSMENT IN THE PIPELINE INDUSTRY

Risk assessment is the process of identifying, describing, and analyzing risk with the following elements:

- Recognition or *identification* of a hazard or potential adverse event, perhaps with definition of accident scenarios in which the hazards are realized or experienced;
- Analysis of the *mechanisms* by which an event can occur and the mechanisms by which the event can create loss;
- Analysis of the *consequences* of an adverse event as a function of various factors of design or circumstance; and
- Estimation of the *likelihood* of the sequences of events that lead to the consequences.

According to Muhlbauer (1999), because the risk of pipeline failure is sensitive to unmeasurable or unknowable initial conditions, risk efforts are often not attempts to predict how many failures will occur or where the next failure will occur. Instead, efforts are designed to systematically and objectively capture everything that is known and use the information to make better decisions.

Risk assessments can guide pipeline operators to make decisions and take precautions that allow the risks to be minimized or avoided entirely. *Risk management* is a systematic focusing of limited resources on those activities and conditions with the greatest potential for reducing risk. In risk management, decision makers take the results from risk assessments and use them to prioritize risk reduction actions. Risk controls can involve measures both to prevent adverse events and to mitigate their magnitude. One reduces the likelihood; the other reduces the severity of impact. Another step in risk management is the monitoring of performance to determine whether risk control measures are effective. The process can be repeated to further address and reduce overall risk.

The first step in defining risk is to identify a potential hazard or dangerous situation and describe the mechanisms by which the hazard can cause harm to people, property, and the environment. Risk is then analyzed for *each* hazard or hazard scenario. In terms that can be analyzed, risk is defined as the product of (*a*) severity of impact and (*b*) the likelihood of impact from an adverse event. The severity of impact, often called consequences, can be expressed in human terms such as fatalities or injuries or some other metric such as dollars lost. The likelihood of occurrence of an adverse event can be estimated with a variety of methods, ranging from prior experience with the frequency of occurrence, perhaps using statistical data of similar events, to computations based on mathematical models. Likelihood can also be determined by examining the probability of the adverse event occurring in a Bayesian sense, a prior perception of probability.

The example of automobile travel can clarify the concepts. The consequences of an automobile crash can be damage to the car and injury or death to the driver or passengers. More than 40,000 Americans are killed in automobile crashes each year, and several hundred thousand more are injured. Fender benders and other minor crashes are even more frequent. From these data, the risk for large automobiles or small, local streets or Interstate highways, fender bender or serious crashes can be quantified. If a person never rides in an automobile, the risk of death, injury, or damage to one's personal property is zero, except as a nonmotorist (e.g., pedestrian, bicyclist). By similar reasoning, a person who makes a living traveling in automobiles is more likely to experience harm than a person who rides occasionally, even given the differences in driving skill. The difference in the likelihood of experiencing harm is a concept known as *exposure.* The greater the exposure, the higher the risk.

Data on pipeline incidents are collected and analyzed by OPS for each reportable safety incident. These data provide the number of incidents that result in death, injury, or significant property damage. They also provide the general causes of these incidents, including damage by outside force, corrosion, construction defects, operator error, natural forces such as ground movement, and many other categories. At some level of aggregation, the data can be used to determine, or quantify, the risk from various types and sizes of pipelines. On the basis of this experience, one can begin to identify factors that determine risk.

The principle of exposure can be applied to pipelines as well. For an individual who seldom crosses or comes near a pipeline right-of-way—a person who has little exposure—the risk is minimal, while people who live, work, or congregate near pipelines have greater exposure. Exposure is a function of time near a pipeline and effective distance. Exposure to the potential dangers of a pipeline leak or rupture is the result of proximity to the pipeline, natural or man-made barriers, and the mobility of people near the pipeline. People pursuing activities on or near the pipeline that can cause damage to the pipeline have the greatest exposure.

SCENARIO-BASED RISK ASSESSMENT

This category of risk assessment includes a number of methods: HAZOP studies, scenario-based fault tree/event tree analysis, and so forth. These techniques are useful for examining specific situations, and often they are used with other techniques.

HAZOP Technique

In the HAZOP study approach, all possible failure modes are examined, but it is very time-consuming and costly. HAZOP analysis is used in the preliminary safety assessment of new systems or modifications of existing systems. A HAZOP analysis involves a detailed examination of pipeline system components to determine the outcome if a specific component does not function as it is designed to (within its normal parameters). Each parameter (e.g., pressure or flow rate) is examined to identify potential changes in the system that are based on changes in the component parameter.

Fault Tree Analysis

In scenario-based fault tree analysis, the sequence of events is traced backwards from a failure. This technique uses most probable or most severe pipeline failure scenarios, and then resulting damage is estimated and mitigation responses and prevention strategies are developed.

Fault tree analysis is a method of risk identification and scenario building in which the outcome of an event is traced backward to all possible causes (Mc^2 Management Consulting 2004). It is a probabilistic top-down analysis that is used to assess the likelihood of occurrence of an undesired system-level event (e.g., a release of product, an explosion), and it can be used to quantify the risk associated with resulting safety hazards. Factors or combinations of factors that could cause the event are put in a structured logic diagram (which takes interdependencies in components into account). The network branches from the outcome event to individual factors (e.g., failure of pump, failure of switch, no response from operator) in a treelike structure. [Additional information is given by Mc^2 Management Consulting (2004), IsographDirect (2004), and Sandia National Laboratories (2004).]

Fault tree analysis can include such factors as natural disasters, human activity, and other externally induced causes. The method can also be used to establish cost-effective troubleshooting procedures based on the factors that are most likely to cause a failure.

Other Probabilistic Risk Assessment Techniques

While fault tree analyses are better suited to examine systems in which the failures of components or processes can be described in terms of pass/fail outcomes (a binary description), they are not ideal for systems in which the processes are not discrete and the outcomes cannot be described simply as pass or fail. (Typically, these are natural events.) Other probabilistic risk assessment techniques have been developed that can consider a range of outcomes of individual processes in a scenario.

An example of scenario-based risk assessment models is the PIPESAFE model (Acton et al. 1998).

INDEX MODELS

Index models use customized algorithms to conduct pipeline risk assessment. There are a variety of index models, including Muhlbauer's

Risk Assessment Methodology, Consequence Modeling (the C-FER method), and the PipeView Risk Model.

Muhlbauer's Risk Assessment Methodology

Muhlbauer (1996, *x*) believes that "data on pipeline failures are still insufficient to perform a thorough risk assessment using purely statistical concepts" and that an assessment using probabilistic theory is not required because the probabilities used in the assessment are of questionable benefit.

A hazard, according to Muhlbauer, is a characteristic that provides the potential for loss; it cannot be changed. Risk is the probability of an event that causes a loss and the magnitude of that loss, and therefore actions can be taken to affect the risk. Thus, when risk changes, the hazard may remain unchanged. Risk can change continuously; conditions along a pipeline are usually changing, and as they change, the risk also changes.

Risk is defined by answering three questions:

- What can go wrong (every possible failure must be identified)?
- How likely is it to go wrong?
- What are the consequences?

In this technique, numerical values are assigned to conditions on the pipeline system that contribute to risk. The score, which reflects the importance of an item relative to other items, is determined from a combination of statistical failure data and operator experience. As do all techniques, this model has a number of assumptions:

- All hazards are independent and additive.
- The worst-case condition is assigned for the pipeline section.
- All point values are relative, not absolute.
- The relative importance of each item is based on expert judgment; it is subjective.
- Only risks to the public are considered, not risks to pipeline operators or contractors.

In Muhlbauer's basic risk assessment model, data gathered from records and operator interviews are used to establish an index for each category of pipeline failure initiator (i.e., what can go wrong and the associated likelihood): (*a*) third-party damage, (*b*) corrosion, (*c*) design, and (*d*) incorrect operations. These four indexes score the probability and importance of all factors that increase or decrease the risk of a pipeline failure. The indexes are summed. The last portion of the assessment addresses the potential hazards, their probabilities of occurring, and their consequences. The consequence factor begins at the point of pipeline failure, called the leak impact factor. The leak impact factor is the sum of the product hazards divided by the dispersion factor.

This basic model can be expanded to include other modules such as the cost of service interruption, distribution systems, offshore pipelines, environment, failure adjustment, leak history adjustment, sabotage, and stress.

Consequence Model (C-FER Model)

C-FER Technologies developed a model that examines isometric thermal radiation distances to determine a burn radius and a 1 percent fatality radius from a natural gas pipeline break. An assumption of this model is that risk can be expressed as the product of failure probability and failure consequences, and reliability is the complement of failure probability. Probability of failure and consequence calculations are conducted by using two C-FER software programs—PIRAMID, which is used to optimize maintenance and inspection decisions, and PRISM, which is used to conduct pipeline reliability analyses (Zimmerman et al. 2002). The model incorporates three factors: a fire model that relates the gas release to the intensity of the heat, a model that provides an estimate of the amount of gas being released as a function of time, and a heat intensity threshold. The model can be used to determine a zone of impact for a pipeline fire. The equation used in the model relates the diameter and operating pressure of a pipeline to the size of the affected areas, assuming a worst-case failure event (Stephens 2000). The model can also be used to determine how the intensity of heat changes with the distance from the fire. From the model, "circles" around a pipeline fire that have equal levels of thermal radiation can be calculated. (In fact, the distance of equal thermal radiation from a pipeline fire may not be circular, depending on the nature of the gas discharge, obstructions of the jet of flowing gas, and delays in ignition. For example, the gas coming out of a ruptured pipe may be discharged in a particular direction or upward from the surface depending on the direction of the jet of flowing gas.)

C-FER calculates the degree of harm to people due to thermal radiation by using a model that relates the potential for burn injury or fatality to the thermal load received. A 30-second exposure time is assumed for people exposed to the fire in the open. In this interval, it is assumed that an exposed person will remain in fixed position for between 1 and 5 seconds (presumably to understand what is happening and react) and then run at 5 miles per hour in the direction of shelter. It is further assumed that a person would find a sheltered location within 200 feet of his or her initial position. It is offered that the heat flux that will cause burn injury is between 1,000 and 2,000 Btu/h/ft^2 (3.2 and 6.3 kW/m^2), depending on the burn injury criterion (e.g., time to blister). The threshold level of heat flux for fatal injury is determined when the chance of mortality is 1 percent; that is, 1 in 100 people directly exposed to this thermal load would not be expected to survive. This heat flux is calculated to be 5,000 Btu/h/ft^2 (15.8 kW/m^2).

C-FER also calculates a lower bound reliability curve based on the probability of a fatality or injury of an individual standing on the centerline of a pipeline. The third calculation is the cumulative frequency of casualties along the length of a pipeline system, called the FN curve. [See Harris and Acton (2001) for more information on these calculations.]

C-FER models the thermal load on wooden structures leading to ignition and fire. One calculation shows that 5,000 Btu/h/ft^2 (15.8 kW/m^2) would correspond to ignition in the presence of a flame source in approximately 20 minutes. It calculates that spontaneous ignition at this level of thermal radiation would not occur.

On the basis of these thermal radiation levels, C-FER calculates the radius of a hazard area as a function of pipeline size (diameter) and operating pressure. The graph of hazard area radius versus maximum operating pressure is shown in Figure D-1. A 36-inch-diameter pipeline operating at a maximum pressure of 1,000 pounds per square inch would have a hazard area radius of 750 to 800 feet. A 6-inch-diameter pipeline operating at less than 500 pounds per square inch would have a hazard area radius of less than 100 feet.

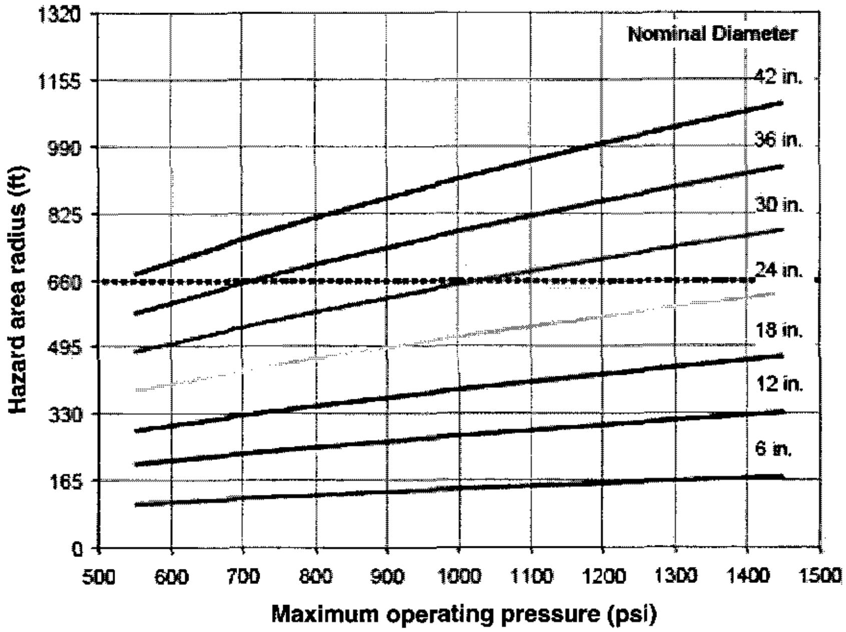

FIGURE D-1 Proposed hazard area radius as a function of line diameter and pressure. (SOURCE: Stephens 2000.)

By using the approach in C-FER's report, it would be possible to calculate hazard area distances for a variety of hazard scenarios involving more hardened structures and different accident scenarios.

PipeView Risk

PipeView Risk is a pipeline risk assessment program that assists pipeline operators in evaluating the current condition of their pipelines and identifying sections of higher risk in order to prioritize maintenance programs (Kiefner & Associates and M. J. Harden Associates 2004). PipeView Risk uses a relative risk ranking model. The analyses are performed by evaluating the physical pipeline attributes (e.g., diameter, grade, and wall thickness) in an algorithm that models the relationship between them. PipeView Risk is designed to be geographic information system (GIS) compatible by starting with an Integrated Spatial Analysis Techniques

(ISAT) database—a family of applications that integrate information from many sources including GIS; the Global Positioning System; pipeline maps; and other operating, monitoring, and maintenance data. The ISAT project was begun at the Gas Research Institute in the mid-1990s.

SUMMARY

A number of risk assessment methods are being used by the pipeline industry to prioritize risk mitigation actions. Regulatory agencies in the United States and abroad have developed risk-based regulations and criteria for safe operation of pipelines. While the risk assessment methodologies in use allow scarce resources to be focused on mitigation of the highest-risk items by emphasizing a single risk number, they do not adequately characterize all the dimensions of risk. A broader characterization of risk, as outlined in Chapter 3, will enable state and local policy makers, with input from stakeholders, to make land use decisions in a systematic manner.

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Study Committee Biographical Information

Don E. Kash, *Chair,* is Hazel Professor of Public Policy in the Department of Public Affairs at George Mason University. He is also guest professor at the Research Academy for 21st Century Development, Tsinghua University, Beijing. He received B.A., M.A., and Ph.D. degrees in political science at the University of Iowa. He was professor of political science at the University of Oklahoma from 1970 to 1991. From 1978 to 1981, Dr. Kash was Chief of the Conservation Division at the U.S. Geological Survey, which was responsible for regulating energy and mineral development on the Outer Continental Shelf (OCS), federal, and Indian lands. The division's responsibilities ranged from economic evaluations of minerals before leasing through establishing the standards for and regulating all of the steps from exploration through development and production to royalty collection. While he was division chief, the organization launched a new centralized royalty collection system, was reorganized, and implemented the regulations for OCS oil and gas operations required by the 1978 Outer Continental Shelf Lands Act Amendments. Dr. Kash has chaired numerous committees including the Marine Board Committee on Lightering; the 1995–1996 Advisory Panel on Technologies to Protect Fish at Dams, the 1994–1995 Advisory Panel on Advanced Automotive Technologies Project, the 1994 Workshop on Global Communications, and the 1991 Workshop on Alaska–California Subsea Water Pipeline for the Office of Technology Assessment; and the Cross-Disciplinary Engineering Research Committee of the National Research Council from 1986 through 1988. In addition, he has served as a member of numerous committees including the Selection Committee, Critical Technologies Institute Science and Engineering Fellows Program, American Association for the Advancement of Science, 1993–1994; the Committee on Transportation Research Centers, Transportation Research Board, National Research Council, 1992–1993; the Committee on New Technology and Innovation in Building, National Research Council, 1990–1992; the Panel on Oil and Gas Development in Hostile Offshore Environments for the Office of Technology Assessment, 1983–1985; and the Marine Board, 1974–1977 and 1985–1988. A Fellow of the American Association for the Advancement of Science, Dr. Kash has also published extensively in the fields of science technology and public policy, energy policy, and policy analysis.

Bruce G. Boncke is President of BME Associates. He holds a B.S. degree in civil engineering from Clarkson College, Potsdam, New York. He has provided consulting services for more than 30 years and has done extensive work on land development projects. He has prepared and conducts training programs for the Monroe County Planning Council, the New York Planning Federation, the New York State Bar Association, and the Home Builders Association. He is past president of both the Rochester Home Builders Association and the New York State Builders Association, and he is the 2003 chairman of the National Home Builders Association Land Development Committee. He is the current president of the New York Planning Federation, a past president of the Rochester Section of the American Society of Civil Engineers, and a member of the New York State Quality Communities Task Force Committee. In New York State, Mr. Boncke has been involved in writing state and local incentive zoning regulations, State Environmental Quality Review Act revisions, wetland delineation and mitigation guidelines, clustering provisions, and conservation easement statutes.

Raymond J. Burby is the Director of the Ph.D. Program in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. Dr. Burby teaches courses in land use and environmental planning, development impact assessment, development management, sustainable cities, hazard mitigation, and research methods. He is a fellow of American Institute of Certified Planners and is a member of numerous professional organizations. Dr. Burby is a former coeditor of the *Journal of the American Planning Association*, has authored or edited 14 books, and has published extensively in planning and policy journals including *Journal of the American Planning Association, Journal of Planning Education and Research, Journal of Policy Analysis and Management, Land Economics,* *Environmental Management*, and *Journal of Environmental Planning and Management*. He is currently principal investigator on a study of urban growth boundaries funded by the National Science Foundation. Dr. Burby received an A.B. degree from the George Washington University and M.R.P. and Ph.D. degrees from the University of North Carolina.

Cynthia Jensen Claus, attorney-at-law, lives and works in Lawrence, Kansas. By appointment of Governor Bill Graves, Ms. Claus served from 1997 to 2003 on the Kansas Corporation Commission, the agency having state regulatory oversight of public utilities (including telecommunications, electricity, natural gas, and water), pipeline safety, transportation, and the production of crude oil and natural gas. During her tenure as Commissioner, she served as the official representative of Kansas to the Interstate Oil and Gas Compact Commission, where she was a member of the Legal and Regulatory Affairs Committee and served on the Steering Committee, the Resolutions Committee, and the Finance Committee. She was also a member of the National Association of Regulatory Utility Commissioners, serving on the Finance and Technology Committee and the Telecommunications Committee. Before her service on the Kansas Corporation Commission, she provided in-house legal services for 16 years (including 5 years as chief counsel) to ARCO Pipe Line Company, a regulated cross-country oil pipeline company. She served as a member of the State Affairs Committee of the Association of Oil Pipe Lines from 1989 to 1995 and as Chairman of the Pipeline Committee of the Texas Mid-Continent Oil and Gas Association from 1994 to 1995. Ms. Claus has an undergraduate degree from the University of Kansas and a law degree from the University of Kansas School of Law, where she was elected to Order of the Coif. She served as a member of the Board of Governors for the Law Society for the University of Kansas School of Law from 1983 to 1985. She also served as the Municipal Judge for the cities of Independence and Cherryvale, Kansas, from 1978 to 1979. In 2003, she was appointed to the American Arbitration Association's panel of neutrals.

Geraldine E. Edens is Office Counsel at McKenna, Long & Aldridge, LLP. Before taking this position, she was Special Litigation Counsel to Cadwalader, Wickersham & Taft's Environmental Law Group. Dr. Edens practices in areas involving environmental litigation, regulatory matters, and issues concerning law and science, and she has performed environmental audits and reviews for a variety of corporate clients in the chemical manufacturing and mining industries. She counsels clients on environmental compliance, the law and science of chemical regulation, toxic tort health claims [asbestos, boron, polychlorinated biphenyls, lead, benzene, methyl tertiary butyl ether (MTBE), etc.], and a wide variety of Clean Air Act issues. Dr. Edens has a broad base of litigation experience, including service as lead counsel on behalf of an intervenor-defendant in a National Environmental Policy Act case challenging a federal grant of a right-of-way for an interstate pipeline and challenging the authority of the Department of Transportation to ban the transport of MTBE in an interstate pipeline. Dr. Edens graduated from the University of Miami School of Law magna cum laude and Order of the Coif, where she was a member of the *University of Miami Law Review.* She has a Ph.D. in education from the University of Florida and M.S. and B.S. degrees from the University of Miami. Dr. Edens is a member of the District of Columbia and Maryland Bars. She is coauthor of two chapters, "Federal Environmental Liability" and "Indoor Air Quality," in *Environmental Aspects of Real Estate Transactions,* and the chapter "Indoor Air Quality" in *Environmental Law Practice Guide: State and Federal Law.* Before joining Cadwalader, Dr. Edens was a professor at the University of Miami, where she was a member of the graduate school faculty.

William L. Halvorson is a research ecologist with the U.S. Geological Survey at the Sonoran Desert Research Station and a professor in the School of Natural Resources, both at the University of Arizona. His research interests include vegetation ecology of arid and semiarid regions, species distribution and diversity, community structure, restoration and management of natural ecosystems, and landscape ecology. He has a bachelor's degree from Arizona State University, a master's degree from the University of Illinois, and a Ph.D. from Arizona State University. He is a member of the California Botanical Society and the Ecological Society of America and serves on the Board of Directors of the Society for Ecological Restoration.

Robert L. Malecki is principal owner of Malecki Consulting, LLC. He provides consulting services to energy-sector clients in the northeastern United States, with an emphasis on environmental assessment and permitting, government and community cooperation, approval acquisition, and design and implementation of environmental protection techniques. He recently retired from the New York State Electric and Gas Company. During the last 10 of his 33 years there he was responsible for environmental planning, regulatory approvals, licensing, construction and operational impact mitigation, compliance, and hazardous waste disposal. Mr. Malecki holds a B.S. in forest science from Pennsylvania State University and has undertaken graduate studies on environmental impact assessment at the College of Environmental Science and Forestry at the State University of New York, Syracuse. He also has taken graduate studies in the management development program at the University of Michigan.

James M. Pates has served since 1986 as the City Attorney of the City of Fredericksburg, Virginia, in which capacity he is responsible for all of the civil legal affairs of the city, including litigation, legislation, and a wide variety of commercial, real estate, land use, and environmental transactions. Since 1990, he has helped lead a national effort by a coalition of environmental, state and local government, and public interest groups to improve pipeline safety. He is one of the founders and currently serves as Vice President of the National Pipeline Reform Coalition. He has testified before Congress on various pipeline safety bills and has authored local, state, and federal legislation aimed at increasing the role of state and local governments in pipeline safety. Mr. Pates is the author of two papers on pipeline safety and the producer of a 1996 public service video, "Out of Sight, Out of Mind: What Every Local Government Should Know About Pipeline Safety." Before taking his current position, he served as legislative counsel to the Subcommittee on Commerce, Consumer, and Monetary Affairs of the Committee on Government Operations, U.S. House of Representatives, and later as government relations counsel for a national trade association in Washington, D.C. Mr. Pates is a magna cum laude graduate of Amherst College and a graduate of the University of Virginia Law School.

Richard A. Rabinow became President of The Rabinow Consortium, LLC, following his retirement from ExxonMobil in 2002 after 34 years of service. At the time of his retirement, Mr. Rabinow was the president of

ExxonMobil Pipeline Company (EMPCo), a position he had held at EMPCo and its predecessor, Exxon Pipeline Company, since 1996. Before that, Mr. Rabinow held the position of Vice President and Lower 48 Manager of Exxon Pipeline Company. He received a B.S. degree in engineering mechanics from Lehigh University and M.S. degrees in mechanical engineering and management, both from the Massachusetts Institute of Technology. During 1994 and 1995, Mr. Rabinow held the position of Senior Vice President, Integrity and Compliance Projects, while on loan to the Alyeska Pipeline Service Company in Anchorage, Alaska. He serves as Vice President of the Board of Trustees of the Houston Arboretum and Nature Center. He is a former member of the American Petroleum Institute and the Association of Oil Pipe Lines and has been a member of the Trans Alaska Pipeline System Owners Committee.

Narasi Sridhar is a Program Director in the Mechanical and Materials Engineering Division at Southwest Research Institute, where he has worked since 1989. At Southwest Research Institute, he has been managing projects related to the licensing of engineered barrier system designs for high-level nuclear waste disposal, safety evaluation of processes to remediate liquid radioactive wastes at Hanford, corrosion mitigation pertaining to gas pipelines, corrosion prediction for chemical process industries, marine corrosion, and aircraft corrosion. Before joining Southwest Research Institute, he was active in the chemical process, pulp and paper, and oil and gas industries. He has more than 20 years of experience in materials development, electrochemistry, and corrosion, and he has been involved in the development of nickel-, cobalt-, copper-, and iron-base alloys for more than 15 years. Dr. Sridhar received a B.S. degree in metallurgy from the Indian Institute of Technology in 1975, an M.S. degree in materials engineering from Virginia Polytechnic Institute and State University in 1977, and a Ph.D. in metallurgical engineering from the University of Notre Dame in 1980. He has published more than 70 papers and has contributed chapters to several handbooks on corrosion and corrosion-resistant alloys. He is a member of the Electrochemical Society, NACE International, ASM International, American Society for Testing and Materials, and the Board of Editors of the journal *Corrosion.* In recognition of his outstanding contributions to corrosion in several industries, he received a NACE Technical Achievement award.

Theofanis G. Theofanous, NAE, is Professor and Director of the Center for Risk Studies and Safety at the University of California, Santa Barbara. He received a Ph.D. from the University of Minnesota and a B.S. degree from the National Technical University, Athens, Greece, both in chemical engineering. From 1974 through 1985, he was a professor and founding director of the Nuclear Reactor Safety Laboratory at Purdue University. Dr. Theofanous is a member of the National Academy of Engineering, a fellow of the American Nuclear Society, and a foreign member of the Ufa Branch of the Russian Academy of Sciences. Among his other honors are the E. O. Lawrence Presidential Medal and an Honorary Doctorate from the University of Laapeenrantaa, Finland. He has published extensively and has received numerous best paper awards. His technical interests focus on multiphase transport phenomena and risk assessment and management in complex technological and environmental systems. He studies methodological issues in treating uncertainty in risk assessments and basic multiphase flow physics, and he works to integrate these basic aspects toward understanding and optimizing system behavior, assessing risks, and improving safety.

Theodore L. Willke is President of TLW Solutions, Inc., a consulting firm specializing in risk management and the application of new and emerging oil and gas pipeline technology. He is a lecturer and faculty advisor in the H. John Heinz III School of Public Policy and Management at Carnegie Mellon University. Dr. Willke received B.S. degrees in astronautical engineering and engineering science from the U.S. Air Force Academy, an S.M. in nuclear engineering from the Massachusetts Institute of Technology, an M.B.A. from the University of Dayton, and a Ph.D. in industrial and systems engineering from the Ohio State University. From 1997 to 2001, he was Director and Chief Executive Officer of Carnegie Mellon Research Institute. Dr. Willke is a member and has served as chair of a pipeline safety advisory committee for the U.S. Secretary of Transportation, Technical Pipeline Safety Standards Committee, Office of Pipeline Safety. He also served as chair of the International Committee on Pipeline Repair and Rehabilitation representing 22 countries for the International Gas Union. Dr. Willke served as Vice President in charge of pipeline, distribution, and environment and safety technology research and development at the Gas Research Institute, where he worked in various capacities from 1984 through 1997. He managed the design and construction of two major pipeline test facilities—the Metering Research Facility in San Antonio and the Pipeline Simulation Facility in Columbus, Ohio. He developed and obtained regulatory approval for a new pipeline repair technology and introduced a van-mounted natural gas leak detector to the market. Dr. Willke was chair of the Pittsburgh International Science and Technology Festival and of the technology committee of the New Idea Factory for County Executive Jim Roddy. He is a previous board member of the Ben Franklin Technology Center of Western Pennsylvania and a former board member of PRC International, a pipeline technology research organization. He has published extensively and holds one patent.

Transmission Pipelines and Land Use
A Risk-Informed Approach

Transmission pipelines make up 20 percent of the 1.8 million total miles of pipelines in the United States and transport virtually all of the nation's natural gas and two-thirds of its petroleum products. In the absence of land use policies, development often may proceed adjacent to pipeline rights-of-way or in the vicinity of active pipelines. Pipeline incidents occur almost daily; most are minor, but a few are not. This report calls on the Office of Pipeline Safety in the U.S. Department of Transportation's Research and Special Programs Administration to work with stakeholders to draft guidance on risk-informed land use for policy makers, planners, local officials, and the public.

Also of Interest

Summary of a Workshop on U.S. Natural Gas Demand, Supply, and Technology: Looking Toward the Future
National Academies Press, ISBN 0-309-08964-6, 112 pages, 6 x 9, paperbound (2003)

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TRB Special Report 271, ISBN 0-309-07746-X, 155 pages, 6 x 9, paperbound (2003)

Improving the Safety of Marine Pipelines
National Academies Press, ISBN 0-309-05047-2, 156 pages, 8.5 x 11, paperbound (1994)

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TRB Special Report 219, ISBN 0-309-04665-3, 197 pages, 6 x 9, paperbound (1988)

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EXHIBIT I

Exhibit I

Joint Committee on Administrative Rules

ADMINISTRATIVE CODE

TITLE 77: PUBLIC HEALTH
CHAPTER I: DEPARTMENT OF PUBLIC HEALTH
SUBCHAPTER r: WATER AND SEWAGE
PART 890 ILLINOIS PLUMBING CODE
SECTION 890.1150 WATER SERVICE PIPE INSTALLATION

Section 890.1150 Water Service Pipe Installation

a) Underground Water Service.

Water service pipe shall be installed outside the foundation wall in accordance with either subsection (a)(1) or (2) of this Section and shall comply with the requirements of both subsections (a)(3) and (4) of this Section.

1) Water service and building drain or building sewer may be installed in separate trenches with a minimum of 10 feet horizontal separation. Such installation shall use material listed in Appendix A, Table A (Approved Materials for Building Sewer and Approved Materials for Water Service Pipe), provided that such material is specific for this type of installation. (See Appendix I: Illustration E.)

2) The water service and the building drain or building sewer may be installed in the same trench provided that the water service is placed on a solid shelf a minimum of 18 inches above the building drain or building sewer. For such installation, the building sewer shall be of material listed in Appendix A: Table A (Approved Building Drainage/Vent Pipe) for a building drain. (See Appendix I: Illustration F for the proper installation of water service, building drain and building sewer.)

3) The minimum depth for any water service pipe shall be at least 36 inches or the maximum frost penetration of the local area, whichever is of greater depth.

4) No water service pipe shall be installed or permitted outside of a building or in an exterior wall unless provisions are made to protect such pipe from freezing, in accordance with Section 890.1210(a).

b) Potable Water Piping and Sanitary Sewer Crossing Installation Requirements.

1) Where it is necessary for the potable water piping to pass above or

below a sanitary sewer, such piping shall be installed with a minimum vertical separation of 18 inches for a distance of 10 feet on either side from the center of the sanitary sewer.

2) Where it is necessary for the potable water piping to pass beneath a sanitary sewer or drain, the sanitary sewer or drain shall be constructed of materials as specified in Appendix A: Table A (Approved Building Drainage/Vent Pipe) for building drains, and shall extend on each side of the crossing to a distance of at least 10 feet as measured at right angles to the water line. The potable water piping shall comply with Appendix A: Table A as specified for a water service pipe (Approved Materials for Water Service Pipe). (See Appendix I: Illustration G.)

3) Wet/Dry Bore:
When it is not possible to comply with subsection (b)(1) or (2), a pressure rated pipe approved for building drain material listed in Appendix A: Table A shall encase the water service pipe. The casing pipe shall be sealed with a casing seal and extend 10 feet on either side of the center of the sanitary sewer pipe. The sleeve or case shall be at least 2 times the size of the water service.

c) When it is not possible to comply with subsection (a) or (b), the Department shall be contacted for consideration of alternative methods.

d) Stop-And-Waste Valve. Combination stop-and-waste valves and cocks shall not be installed in an underground potable water pipe. Frost free hydrants and fire hydrants shall not be considered stop-and-waste valves. (See Section 890.1140(e).)

(Source: Amended at 28 Ill. Reg. 4215, effective February 18, 2004)

EXHIBIT J

Exhibit J

ENBRIDGE

Know your neighbor. Know your pipeline.

Informing the public for greater safety

This brochure is provided specifically for emergency responders and local public officials because you have unique informational needs regarding our pipelines and related facilities. Similar information is provided to people involved in excavation-related activity, and also to those who live and work along our pipelines.

For additional information on our emergency response plan, emergency drills, training or specifics on pipeline location, please contact the local Enbridge pipeline office listed at the end of this brochure.

Properties of oil

While you may already be familiar with crude oil and natural gas liquids, we want to make sure you understand how these products behave and how they should be treated in the unlikely event of a pipeline emergency. ***If a nearby Enbridge pipeline transports natural gas liquids, additional information is included with this brochure.***

Crude oil is highly flammable and gives off vapors that are heavier than air; these vapors can travel to a source of ignition and cause flash fires. Crude oil may contain variable amounts of several elements, including hydrocarbons, benzene, nitrogen compounds, sulfur compounds and oxygenated compounds. Should a pipeline emergency occur, contact Enbridge immediately so we can stop the flow of oil.

Unprotected personnel should be cleared from the area. Do not enter a confined space without full bunker gear, including an approved self-contained breathing apparatus. Cool fire-exposed containers with water to prevent vapor pressure buildup and rupture. Sulfur oxides and hydrogen sulfide may be released upon combustion. Never attempt to operate pipeline valves or extinguish a pipeline fire–this could prolong or worsen the incident or cause another pipeline leak.

In the event of a pipeline emergency involving natural gas liquids, evacuate all unnecessary personnel and use an approved self-contained breathing apparatus. Keep surrounding surfaces cool with a water fog or spray.

Setbacks

As counties become more urbanized, more and more new housing and commercial developments are being built too close to pipelines. Public officials can help by verifying that land developers submit plans with the accurate location of nearby pipelines and other buried utilities. Developers should work with local public officials and pipeline operators to plan for appropriate setbacks from pipeline right-of-way. More information about our crude oil pipelines in your community is available from our Right-of-Way department at (715) 394-1577.